sierra research

Report No. SR2004-09-04

Review of the August 2004 Proposed CARB Regulations to Control Greenhouse Gas Emissions from Motor Vehicles: Cost Effectiveness for the Vehicle Owner or Operator

Appendix C to the Comments of The Alliance of Automobile Manufacturers

September 22, 2004

prepared by:

Sierra Research, Inc.
1801 J Street
Sacramento, California 95814
(916) 444-6666

Report No. SR2004-09-04

Review of the August 2004 Proposed CARB Regulations to Control Greenhouse Gas Emissions from Motor Vehicles: Cost Effectiveness for the Vehicle Owner or Operator

Appendix C to the Comments of The Alliance of Automobile Manufacturers

Prepared for:

Alliance of Automobile Manufacturers

September 22, 2004

Prepared by:

Thomas C. Austin
Thomas R. Carlson
James M. Lyons
Frank DiGenova
Garrett D. Torgerson

Sierra Research, Inc.
1801 J St.
Sacramento, CA 95814
(916) 444-6666

Review of the August 2004 Proposed CARB Regulations to Control Greenhouse Gas Emissions from Motor Vehicles: Cost Effectiveness for the Vehicle Owner or Operator

Table of Contents

List of Tables

1.0 Summary

In support of its proposed greenhouse gas regulations, the CARB staff devised an estimate of the vehicle technology costs and benefits of its proposed standards, which is summarized in various documents including the Initial Statement of Reasons for Proposed Rulemaking dated August 6, 2004, as revised on September 10, 2004 (the "ISOR materials"). Under the current schedule allowed for the consideration of public comment on the CARB staff proposal, it is necessary to complete analyses and submit written reports to CARB by September 23, 2004.

In the limited time available for review of the proposed regulations, it has been possible to identify a number of errors in the estimation of compliance costs and fuel consumption in the ISOR materials. Some of those errors can be corrected in a straightforward manner while others include the use of flawed fundamental assumptions that affect the entire analysis performed by CARB staff. With respect to the former, we have developed estimates that address and correct specific errors identified in Section 4 of this report. Unfortunately, three flawed assumptions could not be adequately addressed in the timeframe provided by CARB for review of those ISOR materials.

The first assumption in the ISOR materials that we could not adequately address is that the automotive industry has the economic and human resources necessary to develop and produce the required technology changes by 2016. CARB provides no support for this assumption and our analysis indicates that vehicle design changes would need to occur at a rate that substantially exceeds historical practice, unless compliance is achieved by shifting motorists into smaller, lower performance vehicles. Information we received from some manufacturers indicates that compliance with the proposed regulations is not feasible in the absence of an increase in consumer preferences for such vehicles. Without engine downsizing and increased consumer preference for smaller vehicles, the level of engineering activity that would be required to comply with the proposed regulations is nearly double current levels. There may not be sufficient lead time for some or all manufacturers to acquire the necessary level of trained, experienced professionals. Attempting to comply with current engineering resources would require the immediate initiation of parallel development efforts of technologies with which the industry has limited experience. Prudent engineering practice dictates that new technologies be phased into production in a manner that provides some manufacturing and customer service experience with a single car line. This allows unforeseeable problems to be resolved without the economic and product reputation risk associated with simultaneous deployment of a new technology across multiple car lines. However, this practice could not be followed if manufacturers are to comply with the proposed regulations on a normal product development schedule.

The second assumption implicit in the ISOR materials that we did not have the time to adequately address was that adoption of the proposed rule will result in nationwide deployment of the technologies that are needed for compliance with the California rule.

This critical assumption, which is not justified by CARB staff, substantially reduces the apparent cost of compliance with the proposed regulations by providing economies of scale. However, it is unlikely that the automobile industry will deploy outside of California a large number of technologies whose costs greatly exceed the benefits to consumers.

The third assumption we did not have the time to address was that the cost of compliance would not be significantly affected by the requirement for the carbon dioxide emissions of Medium-Duty Passenger Vehicles (MDPVs) (i.e., Sport Utility Vehicles [SUVs] with a gross vehicle weight rating [GVWR] above 8,500 pounds) to be included in determining compliance with the standard for light-duty trucks equal to or less than 8,500 pounds GVW (LDT2). Since the large SUVs rated above 8,500 pounds emit higher levels of carbon dioxide, their inclusion increases the stringency of the regulation. CARB completely ignored this factor and we did not have access to the sales projections that would be necessary to account for the impact of MDPVs on the cost and feasibility of compliance.

Ignoring the three problems described above,[1] and correcting the other problems with the CARB staff analysis (described in Section 4 below), the average per-vehicle cost of technology required to comply with the proposed regulations is approximately $3,000 per vehicle for the average of all cars and light trucks. The lifetime gasoline savings would average about 1,000 gallons. The cost of the technology is more than double the net present value ("NPV") of the gasoline savings. It should be noted that the large net loss to customers is understated due to our inability to address CARB's assumptions regarding nationwide production and the lack of adequate engineering resources to produce vehicles meeting the proposed standards without reductions in size and performance.

In summary, our analysis indicates that the proposed regulation will not come close to providing fuel savings that are sufficient to offset the increase in vehicle prices required to achieve compliance under any plausible assumptions about the typical vehicle ownership period in California and the value normally placed on future operating cost savings. The proposed rules will therefore not be cost-effective for the average California driver, and there is no evidence in the ISOR materials to indicate whether the proposed rules will be cost-effective for <u>any</u> California drivers. In addition to not being cost-effective, the proposed rules will have adverse impacts on the California environment and economy as documented in other reports that present the results of analyses in which we have been involved.

[1] It should also be noted that we have not had the time to account for the fact that the mix of models sold in California is not the same as the mix of models sold nationwide. To the extent that California consumers are purchasing larger or more powerful vehicles with lower fuel economy, the stringency of the proposed standards is greater than assumed in our analysis. Based on personal communications with representatives of Alliance member companies, this is a significant factor for some manufacturers.

2.0 Introduction

On August 6, 2004, CARB released the Initial Statement of Reasons (ISOR) in support of a proposed regulation of greenhouse gas (GHG) emissions from passenger cars and light-duty trucks. Table 1 summarizes the proposed standards and shows the level of fuel economy that must be achieved to meet the standards, assuming the use of conventional air conditioning (A/C) systems and no additional control of methane or nitrous oxide emissions. Table 2 shows the level of fuel economy required to achieve compliance assuming "credits" are earned through the use of alternative A/C systems using HFC-152a refrigerant.

Table 1
Proposed "Climate Change Emission Standards"
and Associated Fuel Economy With Conventional A/C Systems

		---- Passenger Cars/LDT1 ----		------- LDT2/MDPV -------	
	Year	Equivalent CO_2	Fuel Economy	Equivalent CO_2	Fuel Economy
Near-Term	2009	323 g/mi	27.6 mpg	439 g/mi	20.3 mpg
	2010	301 g/mi	29.7 mpg	420 g/mi	21.2 mpg
	2011	267 g/mi	33.5 mpg	390 g/mi	22.9 mpg
	2012	233 g/mi	38.4 mpg	361 g/mi	24.7 mpg
Mid-Term	2013	227 g/mi	39.4 mpg	355 g/mi	25.1 mpg
	2014	222 g/mi	40.3 mpg	350 g/mi	25.5 mpg
	2015	213 g/mi	42.0 mpg	341 g/mi	26.2 mpg
	2016	205 g/mi	43.7 mpg	332 g/mi	26.8 mpg

Table 2
Proposed "Climate Change Emission Standards"
and Associated Fuel Economy with Alternative A/C Systems

		---- Passenger Cars/LDT1 ----		-------- LDT2/MDPV -------	
	Year	Equivalent CO_2	Fuel Economy	Equivalent CO_2	Fuel Economy
Near-Term	2009	323 g/mi	26.3 mpg	439 g/mi	19.5 mpg
	2010	301 g/mi	28.1 mpg	420 g/mi	20.3 mpg
	2011	267 g/mi	31.5 mpg	390 g/mi	21.8 mpg
	2012	233 g/mi	35.8 mpg	361 g/mi	23.5 mpg
Mid-Term	2013	227 g/mi	36.7 mpg	355 g/mi	23.9 mpg
	2014	222 g/mi	37.5 mpg	350 g/mi	24.2 mpg
	2015	213 g/mi	38.9 mpg	341 g/mi	24.8 mpg
	2016	205 g/mi	40.4 mpg	332 g/mi	25.4 mpg

As shown in the above tables, the proposed form of the standards is one schedule of fleet average CO_2-equivalent emission rates for passenger cars and the smallest light-duty trucks (LDT1) and a separate schedule of maximum emission rates for heavier light-duty trucks (LDT2 and MDPVs).[1] (Some averaging between the categories would be allowed.) Unlike a preliminary proposal published on June 14, Small Volume Manufacturers, Independent Low Volume Manufacturers, and Intermediate Volume Manufacturers would not become subject to standards until the 2016 model. In addition, the standard these smaller manufacturers would be required to meet would be equal to the CO_2 emissions of "comparable vehicles" produced by larger manufacturers in the 2012 model year. In other words, a smaller manufacturer of high performance sports cars would only have to achieve the same CO_2 emissions rate in 2016 as larger manufacturers achieved for high performance sports cars four years earlier.

When fully phased in, the 205 g/mi standard for passenger cars and LDT1 vehicles is equivalent to 43.7 mpg for a vehicle that uses a conventional, HFC-134a air conditioning system and uses no measures to reduce nitrous oxide (N_2O) or methane from the assumed baseline levels. This is 59% higher fuel economy than required under the Corporate Average Fuel Economy (CAFE) standards for passenger cars. Passenger cars converted to HFC-152a refrigerant (which reduces the CO_2-equivalent emissions due to A/C refrigerant by more than 90%) and that also use a variable displacement compressor with "external control" earn a credit of 16.6 g/mi, which allows compliance with the standard with CO_2-equivalent emissions (including methane and nitrous oxide) of 221.6 g/mi. To account for the methane and nitrous oxide, exhaust CO_2 emissions would need to be 219.7 g/mi, which is equivalent to 40.4 mpg. Assuming a manufacturer could find some way to eliminate methane and N_2O emissions (which does not appear possible), the required level of exhaust CO_2 emissions would be 221.6 g/mi, which is equivalent to 40.0 mpg. In other words, the fuel economy level needed to comply with the proposed standard for passenger cars is <u>at least</u> 47% higher than the federal CAFE standard.

The 332 g/mi standard for LDT2/MDPV vehicles is equivalent to 26.8 mpg for a vehicle with a conventional air conditioning system. This is 21% higher than the recently adopted 2007 federal CAFE standard for light-duty trucks of 22.2 mpg. With an alternative air conditioning system (earning an 18.5 g/mi credit), the required level of fuel economy drops to 25.4 mpg.

It also should be noted that, due to differences in consumer preference in California, the fuel economy of passenger cars and light trucks is lower than the national average for some manufacturers. As a result, the percentage improvement in fuel economy required to comply with the proposed standards is even greater than estimated herein.

According to the August 6 ISOR, the ultimate (year 2016) cost increase associated with the proposed standards is $626 for passenger cars and LDT1s and $955 for

[1] The proposal requires Medium-duty Passenger Vehicles (MDPVs) between 8,500-10,000 lbs. GVW to be included with manufacturers' LDT2 vehicles when determining compliance. This increases the stringency of the LDT2 standards for manufacturers like GM and Ford who produce Sport Utility Vehicles in the 8,500-10,000 lb. GVW range.

LDT2/MDPVs. These were reported to be the average costs for the six largest manufacturers. These costs were based on assumptions regarding the fraction of each manufacturer's production that would require the most effective combinations of technology available in the "mid-term." However, the assumed technology use fractions were obviously inconsistent with the assumptions used to set the standards. For example, the PC/LDT1 standards are based on mid-term technology being applied to 100% of GM vehicles, but the cost estimate is based on the assumption that GM will only be required to apply mid-term technology to 34% of its 2016 model year PC/LDT1 vehicles. Similar underestimates of required technology use were made for other manufacturers. When these discrepancies were pointed out by Sierra, CARB staff agreed that an error had been made. On September 10, 2004, CARB posted an addendum to the ISOR containing the CARB staff's revised estimates.

Based on the revised CARB staff estimates, the cost increase associated with the proposed 2016 standards is $1,064 for passenger cars and LDT1s and $1,029 for LDT2/MDPVs. Costs of the 2012 standards, originally estimated at $292 for PC/LDT1 and $308 for LDT2/MDPV, were increased to $367 for PC/LDT1 and reduced to $277 for LDT2/MDPV.

The ISOR says that vehicle owners will realize a net savings as a result of the improved fuel economy. The money saved as the result of improved fuel economy is projected to exceed the cost of the design changes required to meet the proposed standards by a wide margin. Although no estimates of the per-vehicle fuel cost savings appear in the August 6 ISOR, or in the addendum posted on September 10, Sierra was provided Excel files showing the calculations used to determine fuel cost savings. For passenger cars, the spreadsheets were set by the CARB staff to sum fuel costs over a 16-year period and convert them to a net present value (NPV) using a discount rate of 5%. For light-duty trucks, fuel cost savings were summed over a 19-year period and converted to an NPV using a 5% discount rate. Table 3 summarizes the technology cost estimates and fuel savings estimated by CARB staff. Lifetime reductions in total gasoline consumption and CO_2 emissions were estimated in the CARB spreadsheets based on an assumed 202,329 lifetime average mileage for passenger cars and 223,969 lifetime average mileage for light-duty trucks. The spreadsheet calculations do not account for any increase in automobile travel induced by lower fuel costs (i.e., a "rebound effect").

Table 3
CARB Estimates of Cost and Fuel Savings for the Proposed 2016 Standards

Standards	Increased Vehicle Price	Gallons of Gasoline Saved	Present Value of Gasoline Savings
2012 PC/LDT1: 233 g/mi	$367	1,630	$1,980
2016 PC/LDT1: 205 g/mi	$1,064	2,283	$2,773
2012 LDT2/MDPV: 361 g/mi	$277	1,881	$2,215
2016 LDT2/MDPV: 332 g/mi	$1,029	2,624	$3,090

At the request of the Alliance of Automobile Manufacturers, we have performed a detailed review of the assumptions and analyses supporting the proposed regulations, in order to determine whether the proposed standards meet the requirement of cost-effectiveness as defined by the CARB staff. This work included estimation of some of the changes in technology and some of the associated costs of the proposed standards, using some of the same assumptions as the CARB staff, combined with an independent review of some of critical engineering and economic elements in the ISOR materials.

Organization of the Report

Immediately following this introduction, Section 3 provides a summary of the CARB staff analysis that supports the proposed standards and identifies problems with certain assumptions and calculations used in that analysis. Section 4 summarizes the problems with CARB's analysis that have been identified by Sierra and that could be assessed in the time permitted in order to prepare comments for the current rulemaking. A series of attachments and electronic files (the latter filed with this report at CARB and available upon request from Sierra) provide more detailed analyses.

3.0 The CARB Staff Analysis

The Initial Statement of Reasons (ISOR) for the proposed regulation includes sections related to the following subject areas:

- The environmental and human health impacts of climate change;
- The feasibility and cost of technologies to reduce greenhouse gas emissions from motor vehicles;
- Estimates of the emissions reductions and net lifetime costs of various combinations of technologies;
- The procedure used for developing the proposed standards; and
- The estimated environmental and economic impact of the proposed standards.

Environmental and Health Effects

Although the section of the August 6 ISOR dealing with the environmental and human health impacts of climate change is designed to create the impression that the regulation of greenhouse gas emissions from vehicles sold in California will be beneficial, there has been no attempt to quantify the benefits. Neither is there any analysis showing that the proposed regulations would actually result in a net reduction in greenhouse gas emissions on a global basis. (This is a significant issue given the flexibility manufacturers have under the federal CAFE standards to offset the sale of vehicles with higher fuel economy in California with the sale of vehicles with lower fuel economy in other states.) This issue is being addressed in more detail in other studies.

Baseline Emissions Estimates

The ISOR materials characterize methane from motor vehicles as “negligible” and nitrous oxide emissions from motor vehicles as “decreasing . . . due to increasingly stringent NOx control technologies.” There is no suggestion in the report that specific control measures for either of these two compounds need to be pursued; however, the report says that including methane and nitrous oxide in the calculation of total greenhouse gas emissions “may encourage more development work.” CARB’s analysis assumes baseline emissions of methane and nitrous oxide are 0.005 and 0.006 g/mi, respectively. Multiplied by their respective global warming potential (GWP), the CO_2-equivalent emissions are 0.12 g/mi for methane and 1.78 g/mi for nitrous oxide. (For comparison purposes, the CO_2 emissions of a passenger car achieving the 27.5 mpg CAFE standard are 322.5 g/mi.)

HFC-134a emissions from air conditioning systems are identified as a significant source of greenhouse gas emissions that could be further controlled. The “direct” emissions of HFC-134a (i.e., releases to the atmosphere from leaks, accidents, servicing, and dismantling) are estimated to average 85 grams per year (which is equivalent to 110,500 grams of CO_2). Table 4 summarizes the staff's estimates of baseline emissions for a passenger car that just meets the 27.5 mpg CAFE standard.

Table 4
Baseline Greenhouse Gas Emissions from Passenger Cars

Source	Emissions	CO_2-Equivalent Emissions	Percent of Total CO_2-Equivalent
Exhaust CO_2 during CAFE Testing	322.48 g/mi	322.48 g/mi	92.46%
Exhaust Methane	0.005 g/mi	0.12 g/mi	0.03%
Exhaust Nitrous Oxide	0.006 g/mi	1.78 g/mi	0.51%
Direct HFC-134a Emissions	0.007 g/mi	9.00 g/mi	2.58%
"Indirect" AC Emissions (CO_2)	15.40 g/mi	15.40 g/mi	4.42%
TOTAL	-	348.78 g/mi	100.00%

Emissions Control Technology Analysis

The technology assessment contained in the August 6 ISOR is a slightly revised version of the assessment contained in a draft report published on April 1, 2004, and relies heavily on an interim draft report published by the Northeast States Center for a Clean Air Future (NESCCAF). The potential for reducing exhaust CO_2 emissions is addressed in two ways: (1) reducing emissions during the CAFE test procedure; and (2) reducing emissions through reduced air conditioning compressor load. The CAFE-related technologies described in the ISOR include the following:

- Variable valve lift and timing;
- Turbocharging with engine resizing;
- Cylinder deactivation;
- Increased number of transmission gears;
- Automatically shifted manual transmissions;
- Electric power steering;
- Higher efficiency alternators;
- Gasoline direct injection;
- Hybrid drivetrains;
- Engine friction reduction;
- Reduced aerodynamic drag; and
- Lower rolling resistance tires.

Although there is a general discussion of the way in which each of the above-listed technologies can reduce CO_2 emissions, there is no reference to any literature describing the magnitude of the CO_2 emission reductions that are achievable. This may result from the fact that the relevant literature addresses the technological issue in its most commonly understood form, by describing potential effects on fuel economy or fuel consumption, not as methods to reduce CO_2. There is also no reference to the CO_2 reduction potential associated with weight reduction. In fact, two tables from the NESCCAF report (II-8 and III-1) summarizing the CO_2 reduction potential of various technologies were modified to delete estimates for weight reduction before they were reproduced in the August 6 ISOR. The ISOR points out that CARB "will not rely on weight reductions in setting its climate change emission standards," but also states that "manufacturers would still have the option of lowering weight to improve CO_2 emission performance." One effect of this omission is to deprive CARB of any quantitative estimate by the CARB staff of the likely weight reductions for some vehicle models in California if the proposed rules take effect, or likely changes in the overall weight of the California new-vehicle fleet if CO_2 emissions are to be controlled.

Table 5 summarizes the estimates contained in the ISOR for the effect of individual technologies. Some of the estimates were prepared by AVL under contract to NESCCAF. Others, however, and in particular the "advanced hybrid" estimate, were the sole product of the CARB staff and apparently differed from the estimates prepared by AVL. Based on explanations provided by AVL during previous CARB workshops, the estimates shown in Table 5 have not consistently been adjusted to a "constant performance" basis. (However, the effect of combinations of technologies described later includes adjustments to maintain constant performance.) It should be noted that the effect of the variable displacement air conditioning compressor is apparently based on operation with the air conditioner turned on. There is proportionally less benefit when accounting for the fraction of time the air conditioner is used.

The CO_2 emissions emitted as a result of the power required to run the air conditioning compressor are referred to in the ISOR as "indirect" CO_2 emissions. The ISOR says that variable displacement compressors can be used in conjunction with "better control systems and condensers and evaporators with improved heat transfer" to reduce the CO_2 emissions associated with running the compressor by 50%. This conclusion appears to be based on the assumption that the engine load requirements for "externally controlled VDCs are lower than those of fixed displacement compressors," which are used by most vehicles produced for sale in the U.S. It was also assumed that the amount of outside air would be reduced, although the amount was not quantified. The ISOR says that the net effect of these changes will be reductions in CO_2 emissions ranging from 1.9-2.5% depending on the vehicle category. Large cars were projected to achieve a 2.3% reduction. That reduction is based on an assumed 29% AC utilization factor in the state of California. The ISOR also states that indirect emissions can be reduced by elimination of "air reheat." Because this requires automated climate controls, it was not assumed in CARB's feasibility analysis. The analysis also did not quantify the potential benefits of revising glass angles, increased cabin insulation, and changing vehicle color.

Table 5 CARB Staff Estimates of CO_2 Reductions Achievable in "Large Cars" and Associated Fuel Economy Changes	CO_2 Change	MPG Change
Coupled Cam Phasers (CCP)	-4%	+4.2%
Dual Cam Phasers (DCP)	-4%	+4.2%
Discrete Variable Valve Lift (DVVL)	-4%	+4.2%
Continuously Variable Valve Lift (CVVL)	-6%	+6.4%
Turbocharging (with engine resize) (Turbo)	-8%	+8.7%
Cylinder Deactivation (Deact)	-6%	+6.4%
5-Speed Automatic Transmission (A5)	-1%	+1.0%
6-Speed Automatic Transmission (A6)	-3%	+3.1%
Automatically Shifted Manual Transmission (AMT)	-7%	+7.5%
Electric Power Steering (EPS)	-1%	+1%
Higher Efficiency Alternator (ImpAlt)	-1%	+1%
Gasoline Direct Injection-Stoichiometric (GDI-S)	-1%	+1%
Variable Displacement AC Compressor (VDC)	-9%	+9.9%
Aggressive Shift Logic, Improved Torque Converter + Reduced Aero Drag, Rolling Resistance, Engine Friction	-5%	+5.3%
Camless Valve Actuation (i.e., VVLT)	-16%	+19.0%
Mild Hybrid (42-volt, 10 kW) (ISG)	-6%	+6.4%
Advanced Hybrid	-54%	+117.4%

"Direct" AC emissions (i.e., emissions of the refrigerant itself) are estimated at 6 g/mi CO_2-equivalent from "regular" leakage; 2 g/mi from "irregular" emissions (service and accidents), and 0.5 g/mi from eventual scrappage. The ISOR estimates that leakage emissions can be reduced by 50% through "upgrades to a few key components (e.g., compressor shaft seal)"; however, there is no testing or other documentation referenced to support this estimate.

Replacement of HFC-134a with HFC-152a in a system with 50% leakage reduction is estimated to reduce total CO_2-equivalent emissions by 94%, primarily due to the 91% lower GWP of HFC-152a.

Individual Technology Costs

The costs of the various design changes assumed by the CARB staff are shown in Table 6. These estimates were usually based on the cost estimates contained in the NESCCAF report. Those estimates were based primarily on vendor prices or other sources (the specific sources of which are undocumented) estimated by Martec, Inc., a NESCCAF contractor, that were multiplied by a factor of 1.4 to translate them to a retail price

Table 6 CARB Staff Estimates of Retail Price Increase For Various Technologies Applied to a "Large" Car and Associated Fuel Economy Changes	Price	MPG Change
Coupled Cam Phasers (CCP)	$161	+4.2%
Dual Cam Phasers (DCP)	$196	+4.2%
Discrete Variable Valve Lift (DVVL) (with DCP)	$357	+4.2%
Continuously Variable Valve Lift (with DCP)	$581	+6.4%
Turbocharging (with engine resize)	-$210	+8.7%
Cylinder Deactivation (Deact)	$113	+6.4%
5-Speed Automatic Transmission (A5)	$140	+1.0%
6-Speed Automatic Transmission (A6)	$105	+3.1%
Automatically Shifted Manual Transmission (AMT)	$0	+7.5%
Electric Power Steering (EPS)	$39	+1%
Higher Efficiency Alternator (ImpAlt)	$56	+1%
Gasoline Direct Injection-Stoichiometric (GDI-S)	$259	+1%
Modified AC Compressor and HFC-152a refrigerant	$88	+9.9%
Aggressive Shift Logic, Improved Torque Converter + Reduced Aero Drag, Rolling Resistance, Engine Friction	$125-145	+5.3%
Camless Valve Actuation (i.e., VVLT)	$637	+19.0%
Mild Hybrid (42-volt, 10 kW, motor assist) (ISG)	$1107	+6.4%
Advanced Hybrid	$4009	+117.4%

equivalent (RPE) basis. However, CARB staff discounted some of Martec's cost estimates by 30% to account for "unforeseen innovations in design and manufacturing" that the ISOR says will occur based on previous experience. CARB also reduced Martec's cost estimate for replacing overhead valve engines with dual overhead cam engines by $250 for V-6 engines and $300 for V-8 engines to back out the cost premium for an aluminum block. On an RPE basis, the cost of the conversion was reduced by $350 for V-6 engines and $420 for V-8 engines, cutting in half Martec's estimate for the cost premium of a dual overhead cam (DOHC) engine compared to an overhead valve (OHV) engine. How CARB determined the cost premium for an aluminum block was not explained.

CARB's estimated cost premium for DOHC engines has a substantial effect on the cost estimates for adding fuel economy improvement technology to light-duty trucks because CARB's analysis assumes that all future truck engines use technology that requires DOHC engines to meet the proposed greenhouse gas emissions standards. In fact, all trucks not in the "large" category are assumed to use DOHC engines under the 2009 baseline forecast CARB has used.

As shown in Table 6, the RPE for turbocharging is -$210; the claimed cost savings is based on the assumption that V-6 engines can be replaced with less expensive inline engines when turbocharging is used to achieve constant performance. There are other downward adjustments to the RPE costs for other technologies that CARB also assigns when turbocharging is assumed. These adjustments are not described in the ISOR; however, they can be seen in the spreadsheets that CARB used to construct the values reported.

2009 Baseline Forecast

Before using combinations of the technologies listed in Table 6 to determine the "maximum feasible" level of exhaust CO_2 reductions, an estimate was made by the CARB staff (and/or the NESCCAF contractors or staff) to predict how CO_2 emissions will change by 2009 in the absence of a CARB regulation. The 2009 "future baseline" was constructed assuming the same reduction in 0-60 mph acceleration times that were used in the NESCCAF report. CARB followed the assumption in the NESCCAF interim draft report that there would be no significant increase in weight for light-duty trucks, despite a clear trend. The rationale for ignoring the weight trend for trucks is that changes in federal CAFE standards will stop that trend. (Implicit in CARB's analysis is the assumption that manufacturers will respond to increased CAFE requirements by <u>reducing vehicle weight</u> from what it otherwise would have been, which underscores the importance of the CARB staff's error in failing to consider weight reduction as a consequence of the proposed rule.) The forecast also assumes increased use of variable valve lift and timing and transmissions with a greater number of gears. (As discussed below, these future baseline assumptions predict that manufacturers will deliberately switch to more expensive transmissions and engine technology, instead of using less expensive alternatives that would simultaneously improve fuel economy.)

The 2009 baseline technology assumptions are said to be based on "market research" by one of the NESCCAF contractors. According to the NESCCAF report, Martec, Inc. "conducted detailed market research into Original Equipment Manufacturer (OEM) product plans and developed a database of estimated 2009 vehicle platforms under baseline conditions." (Based on our private communications with OEMs representing well over 50% of total vehicle sales, there was no such disclosure of product plans to Martec. To the contrary, it appears that Martec may have contacted and attempted to interview the engineering or product staffs for some OEMs, but did not receive any concrete information.) The technology combinations assumed to be representative of the projected 2009 baseline are shown in Table 7.

Table 7
CARB's Projected 2009 Baseline Assumptions

Vehicle Category	Technology	CO_2 Change*	Cost Change
Small Cars	DVVL, DCP, A5	-2.6%	+$308
Large Cars	DVVL, DCP, A6	-6.6%	+$427
Minivans	DVVL, CCP, A5	-6.4%	+$315
Small Trucks	DVVL, DCP, A6	-9.0%	+$427
Large Trucks	CCP, A6	-5.5%	+$126

*Relative to the 2002 baseline.

To put the significance of these technology assumptions into context, consider that Table 6 shows that automatically shifted manual transmissions can be used to increase the fuel economy of a large car by 7.5% (a 7% CO_2 reduction) at zero cost. The projected 2009 baseline instead assumes that manufacturers will spend $427 to reduce CO_2 by only 6.6%. As described below, the relatively low cost estimates that CARB has made for achieving further reductions in fuel consumption and CO_2 emissions result from undoing the technology changes that are in the projected baseline.

Emission Reduction and Cost Estimates for Combinations of Technology

The ISOR includes tables showing the effect of various technology combinations on the cost and greenhouse gas emissions of future vehicles. The combinations were apparently suggested in consultation with AVL and represent technologies that are compatible on an engineering basis. Most of the emissions reductions were based on the use of AVL's vehicle simulation model (called "CRUISE"); however, the final estimates include the use of multiplicative and subtractive adjustment factors to account for certain technologies.

To achieve reductions in CO_2 emissions beyond the projected 2009 baseline case, CARB concludes that the optimum package of "near-term" design changes for "large cars" consists of (using the abbreviations shown in Tables 5 and 6 above) GDI-S, DCP, Turbo, AMT, EPS, ImpAlt, VDC, and a package of miscellaneous improvements consisting of aggressive shift logic, reduced aerodynamic drag, tires with lower rolling resistance, and reduced engine friction. This package is projected to achieve a 22.1% reduction in CO_2 emissions compared to the projected 2009 baseline while simultaneously reducing the price of the car by $65.

It is not possible to determine how this price reduction was calculated from the ISOR; however, spreadsheets obtained from CARB make it possible to duplicate most of the numbers. As shown in Table 7, the projected 2009 baseline vehicle is assumed to be equipped with discrete variable valve lift, dual cam phasers, and a 6-speed automatic transmission. Those technologies are estimated to increase the cost over the 2002 baseline by $427 while reducing CO_2 emissions by just 6.6%. Under the proposed near-term standards, CARB assumes that the 6-speed automatic transmission is replaced by an automatically shifted manual transmission that costs $105 less. The V-6 engine with DVVL is also assumed to be replaced by an inline 5-cylinder turbocharged GDI-S engine that costs almost $300 less.[1] Offsetting this cost savings is $87.50 for an alternative air conditioning system, $39 for electric power steering, $56 for an improved alternator, and $145 for the miscellaneous upgrades (reduced aero drag, etc.). CARB reports that the net effect is a $65 cost reduction. (Using CARB's numbers, we independently calculated a $58 reduction, which is the number used in the draft version of the ISOR published on June 14.)

Based on the analysis described above, the CARB staff is claiming that, in the absence of a regulation, manufacturers will incorporate design changes into large cars that will increase their price by $427 and reduce their fuel consumption by 6.6%. But under the proposed regulation, manufacturers will be able to make design changes costing only $362 that provide an additional reduction in fuel consumption of 22.1%. In constructing the final cost estimates, the CARB staff estimates that an average price increase of $219 will be associated with meeting the near-term standards for large cars. This is based on the assumption that half of the vehicles will use the above-described technology combination that saves $65 and the other half will use a combination of technologies that does not include turbocharging and costs $504. (The alternative technology combination benefits from the assumed use of the transmission that saves $105, but not from the savings assumed from resizing the engine.) No rationale is stated for why the option that saves money would not be universally used.

Table 8 summarizes the technology combinations and incremental costs (over the projected 2009 baseline) that CARB assumes will be used to comply with the proposed standards. It should be noted that the extent to which the technologies are required for compliance depends on each individual manufacturer's baseline fuel economy.

There are several curious aspects of the combinations listed in Table 8. First, as noted above, the CARB staff has constructed average cost estimates that do not rely on the lowest cost technology combinations. In addition, there are several technology combinations included in the average that appear unrealistic in terms of emissions compliance and technological readiness. These are shown in **bold** font in the table. For example, it is assumed that the use of a Diesel engine (HSDI) is feasible in small trucks despite any demonstration that emissions control technology is available to achieve the applicable NOx emissions standard with a Diesel engine. Other questionable technologies are electro-hydraulic continuously variable valve actuation (CVAeh) and gasoline homogeneous charge compression ignition (gHCCI). Both of these technologies are at a relatively early stage of development and it is not clear that they can be cost-effectively employed in the mid-term. The ISOR materials and related documents from the CARB

[1] The total cost savings associated with the assumed ability to convert from Vee to inline engines through the use of turbocharging cannot be accurately determined from tables in the ISOR. The backup spreadsheets show that turbocharging combined with engine resizing is assumed to reduce the cost of several other technologies in addition to the basic engine itself.

staff provide no evidence or reasoned analysis to support an assumption that those technologies can be employed in a cost-effective manner during the forecasted period.

Table 8
Summary of Technology Combinations Assumed by CARB Staff

	Vehicle Class	Technologies	RPE	Avg. RPE
Near-Term	Small Car	DVVL, DCP, ATM, EPS, ImpAlt	$149	$382
	Small Car	GDI-S, DCP, Turbo, AMT, EPS, ImpAlt	$812	
	Large Car	GDI-S, Deact, DCP, AMT, EPS, ImpAlt	$504	
	Large Car	GDI-S, DCP, Turbo, AMT, EPS, ImpAlt	-$65	
	Minivan	CVVL, CCP, AMT, EPS, ImpAlt	$696	$358
	Minivan	GDI-S, DCP, Turbo, AMT, EPS, ImpAlt	$572	
	Small Truck	Deact, DVVL, CCP, AMT, EPS, ImpAlt	$244	
	Small Truck	GDI-S, DCP, Turbo, AMT, EPS, ImpAlt	-$77	
	Large Truck	Deact, DVVL, CCP, A6, EHPS, ImpAlt	$663	
	Large Truck	Deact, DVVL, CCP, AMT, EHPS, ImpAlt	$551	
Mid-Term	Small Car	CVVL, DCP, AMT, ISG-SS, EPS, ImpAlt	$1071	$1,204
	Small Car	**GHCCI**, DVVL, ICP, AMT, ISG, EPS, eACC	$1459	
	Large Car	**CVAeh**, GDI-S, AMT, EPS, ImpAlt	$761	
	Large Car	**GHCCI**, DVVL, ICP, AMT, ISG, EPS, eACC	$1575	
	Large Car	GDI-S, DCP, Turbo, A6, ISG, EPS, eACC	$975	
	Minivan	**CVAeh**, GDI-S, AMT, EPS, ImpAlt	$1099	$1,326
	Minivan	GDI-S, CCP, AMT, ISG, Deact, EPS, eACC	$1589	
	Small Truck	Deact, DVVL, CCP, A6, ISG, EPS, eACC	$1470	
	Small Truck	**CVAeh**, GDI-S, AMT, EHPS, ImpAlt	$742	
	Small Truck	**HSDI**, AMT, EPS, ImpAlt	$1141	
	Large Truck	**CVAeh**, GDI-S, AMT, EHPS, ImpAlt	$1495	
	Large Truck	Deact, DVVL, CCP, A6, ISG, EPS, eACC	$1759	

Adverse Attribute Impacts

With the exception of an assumed $50 cost for exhaust system modifications to deal with the increased noise of cylinder deactivation technology, there has been no concrete recognition of how the effects of the technologies assumed in CARB's analysis will affect noise, vibration, and harshness (NVH) or driveability, or how adverse impacts on these attributes will be mitigated. This is a significant issue with respect to several of the technologies. For example, significant benefits are assigned to the use of automatically shifted manual transmissions (AMTs). However, NESCCAF subcontractor AVL has advised that its modeling of AMT did not address the driveability problem associated with a loss of torque transmission during gear changes with this technology. As stated in an appendix to the NESCCAF report prepared by AVL, "In practice there is still a loss of torque during the shift when compared to the automatic transmission" and "the U.S. market does not like the effect of the torque loss during the shift on driveability." To address this problem, AVL indicated that AMTs may require "electric motors to augment the torque applied to the driveline during shifts. In this form, the shift behavior is more like that of an automatic transmission." However, the increased cost and complexity associated with electric motor augmentation to address the driveability problem was not considered in the NESCCAF study.

Standards Setting Process

According to the ISOR, the standards are based on what can be achieved by applying cost-effective technologies to "the manufacturer with the highest average weight vehicles to ensure all manufacturers can comply with the standards." The ISOR says that the process involved starting with the achievable exhaust CO_2 emissions demonstrated in the NESCCAF study (using modeling results for the technology combinations shown in Table 8) and then adjusting this value to account for "the CO_2 equivalent reductions achievable from improved mobile air conditioning systems." For example, if a large passenger car was estimated to be able to achieve 245 g/mi CO_2 exhaust emissions in the near-term, the next step was to <u>subtract</u> 11.1 g/mi from 245, reducing the standard to 234. The value of 11.1 g/mi is the estimated reduction in direct and indirect emissions from the air conditioning system that can be achieved by using a variable displacement air conditioning compressor and leak reduction technology. A vehicle using this technology is given a "credit" of 11.1 g/mi, which is subtracted from the exhaust CO_2 emissions. (For the mid-term standards, the air conditioning adjustment increases to 16.6 g/mi, which is the reduction associated with a variable displacement compressor, leak reduction technology, and replacement of HFC-134a refrigerant with HFC-152a.)

Following the air conditioning adjustment, the next step in determining the standard was described as "include vehicle emissions of CH_4 and N_2O." This would involve adding 1.9 g/mi to the standard. Each vehicle is assumed to emit 1.9 g/mi CO_2-equivalent of methane and nitrous oxide unless the manufacturer submits test data showing a lower emission rate.

The next step in the process was described as "derive the regression lines for setting the near and mid term climate change emissions standards." This apparently involved plotting the "Maximum Feasible" CO_2-equivalent emissions vs. test weight for the example vehicles used in the NESCCAF study and drawing a line through the near-term and mid-term data points. Table 9 shows the "Maximum Feasible" CO_2 levels for the five different vehicle categories, as shown in Tables 6.1-2 and 6.1-3 of the ISOR. (The values reflect the air conditioning adjustment and the adjustment for methane and nitrous oxide described above.) The test weight for each vehicle is based on the values plotted in Figures 6.1-1 and 6.1-2 of the ISOR. (The values for the minivan are not plotted, so the test weight used for the minivan is unknown.)

Table 9 "Maximum Feasible" CO_2 Levels Reported by CARB			
Vehicle Category	Test Weight	Near-Term (g/mi CO_2)	Mid-Term (g/mi CO_2)
Small Car	3000	209	190
Large Car	3625	241	210
Minivan	Not plotted	283	265
Small Truck	4250	303	284
Large Truck	5500	387	354

The proposed standards are points on the graphs where the lines connecting the near-term and mid-term maximum feasible CO_2 levels intersect the test weight of the manufacturer with the "heaviest fleet" (considering only the top six manufacturers by sales volume). Based on an analysis of California-specific registrations, General Motors was determined to be the manufacturer with the "heaviest overall average test weight." The average test weight of GM's cars and LDT1s was calculated to be 3,470 pounds. The weight of GM's LDT2s was calculated to be 5,113 pounds. Where these values intersect the "regression lines" determines the level of the proposed standards.

It should be noted that the technique described above for determining the appropriate value of the standards renders meaningless the weight adjustment that was supposed to have been made to the projected 2009 baseline for small cars. Even if the weight adjustment were used to plot the points used to draw the line showing the relationship between CO_2 and weight for the PC/LDT1 vehicles, by using the current weight of GM's vehicles to find the point on the line associated with the proposed standards, no credit was given for the effect that projected weight increases would have in the future. (In addition, CARB did not account for the weight of GM's Medium-Duty Passenger Vehicles [e.g., Hummer] that are required to comply with the proposed standards.)

A four-year phase-in period is proposed for both the near-term and mid-term standards. In 2009, the standard is set at a level that CARB says is "20% of the way from the highest 2002 baseline CO_2 level of any of the major manufacturers (323 g/mi CO_2 equivalent/mi for PC/LDT1, 439 g/mi CO_2 equivalent/mi for LDT2) to the near-term standard." Table 10 shows the proposed standards and the equivalent fuel economy levels. The 20/40/70/100 phase-in for the mid-term standards is calculated based on the difference between the final near-term standards and the final mid-term standards.

		Table 10 Proposed "Climate Change Emission Standards" ---- Passenger Cars/LDT1 ----		---------- LDT2/MDPV --------	
	Year	Equivalent CO_2	Fuel Economy*	Equivalent CO_2	Fuel Economy*
Near-Term	2009	323 g/mi	27.6 mpg	439 g/mi	20.3 mpg
	2010	301 g/mi	29.7 mpg	420 g/mi	21.2 mpg
	2011	267 g/mi	33.5 mpg	390 g/mi	22.9 mpg
	2012	233 g/mi	38.4 mpg	361 g/mi	24.7 mpg
Mid-Term	2013	227 g/mi	39.4 mpg	355 g/mi	25.1 mpg
	2014	222 g/mi	40.3 mpg	350 g/mi	25.5 mpg
	2015	213 g/mi	42.0 mpg	341 g/mi	26.2 mpg
	2016	205 g/mi	43.7 mpg	332 g/mi	26.8 mpg

* Assuming use of conventional, HFC-134a air conditioning systems and baseline methane/N_2O emissions

Alternative Compliance Methods - Although AB 1493 requires CARB to adopt regulations that allow manufacturers to use "alternative" compliance methods, the ISOR describes restrictions on the allowable alternatives that would eliminate all alternatives except for emissions reductions from vehicles subject to the statute in California.

Estimated Cost of Compliance

According to the ISOR, the ultimate (year 2016) cost increase associated with the proposed standards is $626 for passenger cars and LDT1s and $955 for LDT2/MDPV. These were reported to be the average costs for the six largest manufacturers. These costs were based on assumptions regarding the fraction of each manufacturer's production that would require the most effective combinations of technology available in the "mid-term." However, the assumed technology use fractions were obviously inconsistent with the assumptions used to set the standards. For example, the PC/LDT1 standards are based on mid-term technology being applied to 100% of GM vehicles, but the cost estimate is based on the assumption that GM will be required to apply mid-term technology to only 34% of its 2016 model year PC/LDT1 vehicles. Similar underestimates of required technology use were made for other manufacturers. When these discrepancies were pointed out by Sierra, CARB staff agreed that an error had been made. Revised estimates of cost were subsequently provided in the form of revised version of selected tables and text from the August 6th version of the ISOR.

Based on the revised CARB staff estimates, the cost increase associated with the proposed 2016 standards is $1,064 for passenger cars and LDT1s and $1,029 for LDT2/MDPV. Costs of the 2012 standards, originally estimated at $292 for PC/LDT1 and $308 for LDT2/MDPV, were increased to $367 for PC/LDT1 and reduced to $277 for LDT2/MDPV.

The ISOR says that vehicle owners will realize a net savings as a result of the improved fuel economy. The money saved as the result of improved fuel economy is projected to exceed the cost of the design changes required to meet the proposed standards by a wide margin. Although no estimates of the per-vehicle fuel cost savings appear in the ISOR, Sierra was provided Excel files showing the calculations used to determine fuel cost savings. For passenger cars, the spreadsheets are set up to sum fuel costs over a 16-year period and convert them to an NPV using a discount rate of 5%. For light-duty trucks, fuel cost savings are summed over a 19-year period and converted to an NPV using a 5% discount rate. Table 11 summarizes the technology cost estimates and fuel savings estimated by CARB staff. Lifetime reductions in total gasoline consumption and CO_2 emissions were estimated in the CARB spreadsheets based on an assumed 202,329 lifetime average mileage for passenger cars and 223,969 lifetime average mileage for light-duty trucks. The spreadsheet calculations do not account for any increase in automobile travel induced by lower fuel costs (i.e., a "rebound effect").

Table 11
CARB Estimates of Cost and Fuel Savings for the Proposed 2016 Standards

Standards	Increased Vehicle Price	Gallons of Gasoline Saved	Present Value of Gasoline Savings
2012 PC/LDT1: 233 g/mi	$367	1,630	$1,980
2016 PC/LDT1: 205 g/mi	$1,064	2,283	$2,773
2012 LDT2/MDPV: 361 g/mi	$277	1,881	$2,215
2016 LDT2/MDPV: 332 g/mi	$1,029	2,624	$3,090

Projected Effect on Vehicle Sales and the State's Economy

According to the August 6 ISOR, "The economic impact analysis is based on the staff assessment that the reduced vehicle operating cost resulting from the regulation will be sufficiently attractive to new car buyers to compensate for the vehicle price increase, which results in vehicle sales that are unchanged from the levels that would have been the case without the regulation." However, there was also an analysis described using a model called "CARBITS" that supposedly accounted for the combined effect on sales of a vehicle price increase and an operating cost reduction. The computer program or programs was not provided by CARB and access to it has thus far been refused by the apparent source of the model at the University of California at Davis. Some materials related to the program, including an executable version of one or more of the models included in CARBITS, have been provided by CARB and are being evaluated by National Economic Research Associates. According to the ISOR, the CARBITS model predicts that new car sales will increase slightly in the short term and decline slightly beginning in 2013. Using the EMFAC model, the CARB staff concludes that there will be no significant effect on ozone precursors.

The ISOR also discusses the results of modeling of the entire state economy (using the "EDRAM" model) to account for the net effect of the increased vehicle costs and the operating cost reductions. The lifetime operating cost reductions are based on CARB's estimates that passenger cars accumulate a total of 202,000 miles over a 16-year lifetime and LDT1 and LDT2 vehicles accumulate 219,000 miles and 224,000 miles, respectively.[1] Based on the assumed net savings to California motorists, the ISOR projects that the money saved will be spent in other areas and result in a net increase of 3,000 jobs in 2010, 55,000 jobs in 2020, and 83,000 jobs in 2030. The conclusion stated in the ISOR is "The proposed climate change regulation has a net positive impact on the State's economy."

Analysis of the "Rebound Effect"

A 1999 paper by Greene, et al, from Oak Ridge National Laboratory[2] describes the body of research that supports the existence of a "rebound effect" when automotive fuel economy increases. The rebound effect is basically an extension of the "Law of Demand"—when the cost of something decreases (in this case vehicle travel), there is a natural tendency for consumers to demand more of it. As Greene explains, numerous researchers have documented that a rebound effect exists for increasing automotive fuel economy and Greene concludes that the long-term effect is 20%. In other words, a 100% improvement in fuel economy induces a 20% increase in vehicle travel. In its recent rulemaking regarding light-duty truck fuel economy standards,[3] the National Highway Traffic Safety Administration (NHTSA) also addressed the rebound effect and concluded that the magnitude of the effect was the same as Greene had estimated.

Clearly, the rebound effect would make it difficult for CARB to justify adopting regulations that would have the effect of increasing vehicle travel with the attendant increase in ozone precursor emissions. However, the ISOR claims that the rebound effect will not be significant in California because of "higher income and worse traffic congestion." The stated rationale is that "people value their time highly enough that a few pennies in operating cost savings per mile is not going to encourage them to drive more." The ISOR also contains the statement that "people already drive all they need."

The ISOR says that CARB and the California Energy Commission funded the University of California, Irvine (UCI) to estimate how a regulation resulting in reduced vehicle operation cost (i.e., higher fuel economy, a term that is never used in the ISOR) would affect vehicle miles traveled. According to the ISOR, the UCI study found "when California household income and transportation conditions are accounted for, the rebound estimate is very small." The increase in VMT associated with a 25% reduction in consumption was estimated to be 0.32% in year 2020. Based on the literature, the expected effect would have been 2.5% to 5.0%. As documented in reports prepared by

---

[1] The problems with these estimates are described in detail below and in Attachment C-3.

[2] David L. Greene, et al, "Fuel Economy Rebound Effect for U.S. Household Vehicles," The Energy Journal, Vol. 20, No. 3, 1999.

[3] Light Truck Average Fuel Economy Standards, Model Years 2005-2007 (Docket No.: NHTSA-2002-11419 or 68 FR 16867; April 7, 2003).

NERA and Robert Crawford, the results of the UCI study are inaccurate because of mistakes made in formulating the models used in the study—when those mistakes are corrected, the magnitude of the rebound effect calculated using the UCI methodology is essentially the same as that found elsewhere in the literature. The ISOR also states that the travel demand models used by the Southern California Association of Governments and the Bay Area Metropolitan Transportation Commission show no significant rebound effect. The following section of this report contains an explanation of why travel demand models are not capable of estimating the rebound effect.

4.0 Critique of CARB's Analysis

As mentioned in the Summary section, there are a number of problems with the CARB staff analysis that lead to an underestimate of the cost of compliance and an overestimate of the reductions in fuel consumption, fuel cost, and CO_2 emissions associated with the proposed regulations. Three of those problems are (1) insufficient engineering resources to make the required design changes by 2016; (2) the assumption that design changes necessary for compliance will be deployed nationwide; and (3) the failure of CARB staff to account for the effect of MDPVs on the cost of compliance with the standards proposed for light-duty trucks. The other problems we have identified are as follows:

1. The price of passenger cars in the 2009 baseline (no regulation) case is inflated by unrealistic assumptions about expensive technology changes that will be made in the absence of a regulation.
2. CARB vehicle cost estimates are based on an unrealistic 40% markup factor to vendor-supplied parts prices, which is less than half of the markup required to account for manufacturer costs for research, development, engineering, warranty, overhead, sales and marketing, profit, and dealer margin.
3. CARB failed to account for the integration costs of certain vendor-supplied components that cannot merely be added without other design changes.
4. Cost estimates for technology changes provided by a contractor were arbitrarily discounted by 30% to account for "unforeseen innovations in design and manufacturing."
5. Credit was claimed for significant reductions in aerodynamic drag and rolling resistance despite evidence that customers will not accept such changes and despite the fact that customers do not routinely use OEM replacement tires.
6. CARB assumed that technologies that simultaneously <u>reduce</u> vehicle price and <u>improve</u> fuel economy will be used <u>only if a regulation is adopted</u>.
7. CARB failed to account for California's average 8% sales tax in doing its calculations of net lifetime costs of technology changes.
8. The fuel economy benefits of automatic transmission improvements were inadvertently assigned to both manual transmissions and automatic transmissions.
9. Fuel cost savings are estimated using a single set of driving cycles, and without considering the impact of the relevant technologies based on driving patterns that more accurately represent the way that typical Californians drive.
10. Fuel cost savings were based on inflated estimates of vehicle service life resulting from an obvious mathematical error in CARB's analysis of odometer data from the State's vehicle inspection and maintenance program.
11. The present value of fuel cost savings is based on the unrealistic combination of a 5% discount rate and a 16-19 year payback period, which substantially overstates the value to new vehicle purchasers.
12. The fuel savings calculated for light-duty trucks is substantially overstated by CARB's failure to account for the fuel economy improvement required under the

2007 federal standards and by CARB's failure to account for the effect of minivans on baseline fuel economy.

13. Estimated fuel cost savings ignore the "rebound effect," which is the well-documented increase in travel associated with reductions in vehicle fuel cost.

The following subsections address each of these problems. Detailed analyses of some of the issues are provided in the attachments to this report.

Cost of the 2009 Baseline Car Fleet Has Been Exaggerated

For passenger cars, the NESCCAF/CARB analysis is based on the simplifying assumption that all small cars will use 5-speed automatic transmissions by 2009 and all large cars will use 6-speed automatic transmissions. It is also assumed that all passenger cars will use overhead cam engines with "discrete variable valve lift" (DVVL) and cam phasers. This is projected to result in an average price increase of $308 for small cars and $427 for large cars. Sierra's conferences with large volume manufacturers indicate that these assumptions are incorrect. Changes in engine and transmission technology will not be this dramatic. Our independent analysis, presented in detail in Attachment C-1, shows that such radical changes are not required to maintain compliance with the CAFE standards. Based on information available at the time this report was prepared, Sierra estimates a price increase of $239 for the average 2009 model year passenger car. In contrast, our analysis indicates that NESCCAF/CARB analysis has understated the cost increase required by 2009 for light-duty trucks to comply with the recently adopted increase in CAFE standards.

The significance of CARB's 2009 baseline cost estimates is related more to the assumptions regarding technology change rather than to the increase in price itself. As explained in more detail below, CARB's analysis assumes that manufacturers will make technology changes that are not cost-effective compared to other available technologies. The cost of the proposed standards is then minimized by assuming that greenhouse gas regulations will force manufacturers to reverse technology changes planned for 2009 and use more cost-effective technology.

The 40% Markup Factor is Far Too Low

The CARB report cites an Argonne National Laboratory ("ANL") report and an EPA report to support the staff's estimate that a 1.4 multiplier is appropriate for marking up manufacturing costs to the retail level. In fact, the ANL report estimates the overall multiplier to range from 2.0 to 2.05 based on two different cost breakdowns and profit assumptions. ANL then estimates that the multiplier for components purchased from vendors ranges from 1.50 to 1.56 based on the assumption that vendors bear the costs of "Warranty," "R&D/Engineering," and "Depreciation and Amortization." However, OEMs usually have warranty, R&D, and engineering costs associated with components purchased from vendors. The multipliers developed by ANL may not be unreasonable for their intended purpose in that they were being used to estimate the retail price equivalent of electric and hybrid/electric vehicles. Components such as the battery used in an electric vehicle are likely to be fully developed by a vendor and failures in customer service may be more readily assigned to the battery manufacturer. However, most vendor-supplied components are designed by the OEM, not the vendor, and the OEM has full responsibility for warranty costs as long as the vendor has manufactured the component to the OEM's specifications. In fact, the NESCCAF report specifically states (see page II-17) the following:

> *Additional manufacturer-level costs that were not captured in this analysis but that could be associated with the use of new technologies include:*
>
> - *Engineering costs, including advanced R&D, vehicle design and development engineering for integrating new technologies and software development;*
> - *Warranty and possible recall costs;*
> - *Factory capital costs associated with vehicle-level technology changes;*
> - *Manufacturing costs for powertrain or vehicle assembly.*

Based on the above, more typical vendor-supplied components would have a multiplier of 1.83 using the ANL cost breakdown. It must be noted, however, that many of the cost estimates made by Martec do <u>not</u> include the cost of integrating the component into the vehicle. For components that simply replace other components (e.g., a more efficient alternator), the 1.83 markup factor may be appropriate because there are no significant integration costs. For other components (e.g., cam phasers), however, significant changes to the engine are required to integrate the component. In cases like that, the 2.05 markup factor is more appropriate. The 1.4 multiplier used in the NESCCAF/CARB analysis has therefore understated the cost of compliance by 32%. Additional analysis of this issue is provided in Attachment C-1.

<u>Integration Costs Have Not Been Accounted For</u>

As noted above, many of the technology changes must be integrated into the vehicle in a systematic way, and this integration requirement is generally much more complex than the introduction of new hardware or systems that are normally studied by the CARB staff, such as the after treatment of exhaust emissions of precursor or criteria pollutants or the control of fuel evaporative emissions. In the case of systems like cylinder deactivation, variable valve timing, and variable valve lift, significant changes to the basic engine are required. Martec's analysis did <u>not</u> address the cost of such changes. Such costs are a significant event in a fresh engine design and can be substantial when adapting such technology to an existing engine. We have partially accounted for such cost by applying the more reasonable 2.05 multiplier indicated above to the vendor prices for the additional components. In the case of technologies that adversely affect NVH, additional integration costs are required to mitigate the NVH impacts. Based on the industry's current experience, an integration cost of $220 or more is required to integrate cylinder deactivation into an existing vehicle platform.

A 30% Discount for "Unforeseen Innovations" is Not Justified

CARB staff discounted some of Martec's cost estimates by 30% to account for "unforeseen innovations in design and manufacturing" that the ISOR says will occur based on previous experience. This discount was applied to Martec's estimates for the following technologies:

- Cylinder deactivation;
- Electro-hydraulic camless valve actuation;
- Homogeneous charge compression ignition (HCCI) engines;
- Turbocharging;
- 42-volt hybrid systems; and
- Electric power steering.

Some of these technologies, e.g., electric power steering, have been in mass production for several years. They rely on technologies that are decades old and have little potential for "unforeseen innovations." Other technologies, e.g., electro-hydraulic camless valve actuation, have been under development for a number of years and, while simple in concept, have been prevented from reaching mass production due to significant practical problems. Martec's cost estimates for such technologies are based on information obtained from companies who hope to become <u>vendors</u> of the technology. As a result, their estimates are likely to be somewhat optimistic in the first place. There is no basis for CARB staff to arbitrarily assume that actual costs will be 30% lower, and indeed this would be directly contrary to the advice long given by CARB to the air districts when estimating compliance costs.[1] While CARB claims such reductions are based on the agency's experience, the actual experience of the agency in projecting the cost of new technologies is not consistent with the assumption being made. When CARB adopted its Zero Emission Vehicle mandate in 1990, the staff projected that innovations would result in the cost premium for full-function electric vehicles declining to $1,350 in approximately one decade. In fact, no significant change in the cost premium for electric propulsion systems occurred and, based on the conclusions reached by a panel of experts commissioned by CARB, the cost premium for full-function electric vehicles remains in excess of $10,000. Without the 30% cost reduction assumed by CARB, the cost of the technologies increase by 43%.

[1] Catherine Witherspoon, et al., "Cost-Effectiveness, District Options for Satisfying the Requirements of the California Clean Air Act," California Air Resources Board, Office of Air Quality Planning and Liason, September 1990.

Significant Reductions in Aero and Rolling Resistance are Not Plausible

CARB assumed an 8-10% reduction in aerodynamic drag would be achieved, leading to 1.5-2.0% reductions in CO_2 emissions. There is no evidence that supports that assumption, owing to market-driven styling limitations on reductions in aerodynamic drag. The new Chrysler 300 sedan is a case in point. Its 0.35 drag coefficient is significantly higher than the vehicle it replaces. As reported in the June 2004 edition of *Car & Driver*, "The 300 also represents a return to chiseled three-box proportions after a long run of smooth, cab-forward designs." The commercial success this vehicle is achieving indicates that styling to minimize drag coefficient is contrary to what the market wants. Based on conferences with other OEMs, similar trends toward more classic, chiseled styling are apparent at other companies and similar effects on drag coefficient are expected.

In the case of reduced rolling resistance, CARB assumed a 2% reduction in CO_2 could be achieved through a 10% reduction in rolling resistance. As shown in Attachment C-7, our analysis indicates that (1) the rate of progress in reducing rolling resistance has slowed; and (2) new federal safety standards may limit the extent to which future reductions occur. In addition, CARB's analysis is implicitly based on the assumption that changes in OEM tire rolling resistance will generate benefits over the full life of the vehicle. However, motorists cannot be expected to purchase OEM replacement tires. The NESCCAF/CARB estimates of the benefits of aerodynamic drag and rolling resistance reductions have inflated the fuel economy improvement potential of the technology combinations evaluated by about 4%.

Assuming "Credit" for Certain Cost-Reduction Technologies is Unrealistic

CARB's estimates of compliance costs are significantly affected by the assumptions made regarding the cost and effectiveness of two specific technologies: turbocharging and automated manual transmissions. Compared to the baseline, no-regulation case, CARB assumes that these technologies simultaneously reduce cost and improve fuel economy. On its face, this assumption is irrational. If technologies were really available that simultaneously reduce cost and improve fuel economy, manufacturers would voluntary use them.

Attachment C-5 provides a detailed analysis of why the assumed benefits of turbocharging are not available. Although not mentioned in either the NESCCAF report or the ISOR materials, we have confirmed through personal communications with AVL that the fuel economy improvement assigned to turbocharging assumes the use of premium fuel. The $0.20 per gallon cost penalty for premium fuel completely eliminates the fuel cost savings assumed by CARB. As shown in Attachment C-1, our independent analysis concludes that there is zero fuel economy improvement resulting from the use of turbocharging when regular grade fuel is assumed. In addition, the cost savings that CARB assigned to replacing V6 engines with less expensive inline engines failed to account for the value customers assign to V6 engines. This is also addressed in Attachment C-5.

In the case of automated manual transmissions, CARB's analysis assumes these transmissions cost less than the 5- and 6-speed automatic transmissions assumed to be used in the baseline case while simultaneously providing a fuel economy benefit. As is the case with the turbocharging assumption, manufacturers would voluntarily apply such technology if this were the fact. Here the problem is that manufacturing capacity for such transmissions does not exist and CARB failed to account for the cost of developing such capacity. It should also be noted that Martec specifically stated that its cost estimate for automated manual transmissions covered "piece cost only" and that "US manual transmission capacity does not exist." When the costs of developing the necessary production capacity and retiring existing transmission facilities are considered, it is clear that AMTs cannot be produced for zero incremental cost, as assumed in CARB's analysis. Our independent analysis of some AMT costs, which accounts for the engineering and capital investments ignored in the NESCCAF/CARB analysis, indicates that there is an average $577 price premium relative to conventional 4-speed automatic transmissions.

Sales Tax Should Be Accounted For

CARB's analysis of the consumer benefit of improved fuel economy does not account for sales tax. This has a significant effect on the results. Our independent analysis accounts for an 8% tax on the price increase associated with the technology changes needed to comply with the proposed standards.

Manual Transmissions Were Not Properly Accounted For

The NESCCAF/CARB analysis ascribes significant fuel economy improvements to changes in transmission technology. However, all of the technologies evaluated were automatic transmissions. No technology changes affecting manual transmissions were considered. However, the fuel economy benefits for the automatic transmission technologies were assigned to all vehicles. Since 13% of passenger cars are sold with manual transmissions, the benefits of the automatic transmission technology changes have been overestimated by 15%.[1] Sierra's analysis, described in Attachment C-1, properly accounts for the fraction of manual transmission vehicles in the fleet and assigns the benefits of automatic transmission technology only to that fraction of the fleet equipped with automatic transmissions.

The AVL Results Do Not Represent Actual Driving Conditions

The fuel economy modeling of various technologies by AVL used a single set of driving cycles in order to compare on a relative basis the various technologies and combinations

[1] By applying benefits to 100% of passenger vehicles instead of 87%, the benefits are exaggerated by a factor of 100/87=1.15.

of technologies that NESCCAF chose for its interim report. The ISOR materials then use the AVL results from the interim NESCCAF report for a different purpose—to estimate the overall fuel economy levels that those technologies would achieve in typical or average driving in California, if the proposed regulation is implemented. That was not the purpose of the AVL simulations.

The use of AVL's results from simulated driving with a single set of driving cycles to predict fuel savings on an aggregate basis is not appropriate. The ISOR materials contain no evidence that the fuel economy levels determined from the CAFE test procedure, which contains the driving cycles used by AVL, would reflect the level that motorists achieve under average driving conditions in California, and indeed that is not the purpose of the CAFE test procedures.[1] Based on data gathered in a series of studies from 1997-2000 sponsored by the California Department of Transportation and CARB, many of the technologies that the CARB staff has identified to meet the proposed standards and many alternative technologies will provide fuel economy improvements that are substantially overstated by reliance on a single set of driving cycles like the CAFE test procedures. Sierra's analysis, detailed in Attachment C-1, indicates that for the average California driver, the benefits attributed in the ISOR materials to the proposed standards are inflated by approximately 20 percent.

CARB Staff Overstated Average Vehicle Life

CARB staff's estimates of the benefits of the fuel savings associated with the proposed standards are based on average lifetime vehicle mileages that were erroneously calculated. The staff's estimates of 202,329 lifetime mileage for passenger cars and 223,969 lifetime average mileage for light-duty trucks are based on an obvious mathematical error. The staff failed to recognize that vehicles with higher than average mileage accumulation rates tend to be retired from customer service at an earlier age. Attachment C-3 provides a detailed analysis of this issue and presents data supporting our estimate that the true lifetime average mileage accumulation rate is approximately 155,000 miles for both passenger cars and light-duty trucks. The erroneous lifetime mileage estimates used by the staff inflate the fuel savings by 30-44%.

[1] The CAFE test procedures provide the basis for determining compliance with federal fuel economy standards, and their results permit consumers to make relative comparisons between different vehicles in the marketplace. In 1984, EPA revised the fuel economy labeling program to provide for adjustments to both the City and Highway values achieved on the CAFE test procedure. The annual report on the CAFE program published by NHTSA also explains the difference between CAFE calculations, the EPA fuel economy values and on-road values. The data in Appendix C-2 indicate that the benefits to be obtained in California will fit the pattern that has been well established at the federal level for many years -- that is, the fuel economy achieved by motorists is generally lower than the level on the unadjusted CAFE test procedure.

The Value of Improved Fuel Economy Has Been Overstated

In addition to overestimating the lifetime mileage of vehicles that would be subject to the proposed standards, the CARB staff has assumed that new vehicle purchasers will value the future savings associated with improved fuel economy using a discount rate of only 5%. The discount rate is essentially the opportunity cost of capital. A 5% discount rate implies that the average new car buyer is willing to spend or borrow money in order to obtain a 5% return over time. Current unsubsidized new car loan rates have averaged somewhat over 8% over a recent five-year period. Even if consumers valued fuel economy savings over the 16-19 year period assumed by CARB, no rational consumer would borrow money at 8% in order to obtain a return on investment of 5%. The implied discount rate new car buyers assign to fuel economy improvement is likely to be substantially in excess of 8%. For purposes of this review, Sierra uses an extremely conservative 8% discount rate.

Use of the Wrong Baseline Exaggerates Fuel Savings for Light Trucks

Excel files provided by CARB staff make it clear that the fuel savings assumed for the proposed LDT2 standards are relative to the 2002 baseline. CARB failed to account for the improved fuel economy required to comply with more stringent federal CAFE standards applicable to 2007 and subsequent model years. In addition, CARB excluded minivans from the baseline fuel economy/carbon dioxide calculations. These errors alone result in CARB overestimating the fuel savings due to the LDT2 standards by 45%.

The Rebound Effect Has Been Ignored

As mentioned above, separate analyses prepared by Robert Crawford and NERA demonstrate fundamental problems with the UCI analysis of the rebound effect that CARB relies on. As described below, CARB's analysis based on the use of transportation demand models is also flawed.

In section 12.3.C. of the ISOR, CARB staff presents what is purported to be an analysis of the VMT rebound effect in Southern California that was performed using the Southern California Association of Government's (SCAG) travel demand model for southern California. The results of this analysis in terms of changes in VMT and emissions are presented in Table 12.3-3 of the ISOR. Based on the results, CARB staff claims that the elasticity or VMT rebound with respect to changes in fuel cost is about -0.04. However, CARB staff's decision to use SCAG's travel demand model to assess the travel-inducing effect of reduced vehicle operating expenses is inherently flawed as the model is wholly unsuitable for estimating the VMT rebound effect.

Transportation planners are focused on forecasting traffic flows and identifying potential deficiencies in their local transportation system. While the transportation system may include other modes of travel such as walking, bikes, or railroads, the models are typically used for evaluating the effects of roadway and transit service improvements. For this reason, operating expenses are used only to address shifts between automobiles and transit operations (i.e., mode split). <u>The effect of operating expenses on the VMT by motorists who do not shift modes is not accounted for by the model.</u>

Discussions with Hong Kim on SCAG's modeling staff[1] confirmed that the SCAG transportation demand model referenced by CARB staff in the ISOR does not account for the effect of changes in the cost of gasoline on the number of trips that people make (i.e., their demand for travel). Instead it accounts only for the effect of gasoline price changes on people's decisions to either drive alone, take a bus, or participate in a carpool (e.g., as the cost of driving increases, some people will choose to ride a bus in order to conserve expenses). The point is that the model structure assumes that people's decision to travel is unaffected by the price of fuel. The model will predict that people are taking the same number of trips if gasoline is $2, $5, $10 a gallon. The only role that gasoline price has in the model is related to the driving mode that people choose to get from point A to point B. SCAG's model design inherently assumes that people's response to gasoline price changes is completely inelastic with regard to their demand for travel (in both the short-term and the long-term). This is not a realistic view of how people make travel decisions.

Since SCAG's model accounts only for the effect of fuel price and vehicle operating expenses on travel in a very indirect manner (by shifting person trips from single occupant vehicles to transit and carpools), the response to changes in operating expenses is limited to at most a second-order effect. As a result, the analysis presented in Section 12.3.C is meaningless with respect to the estimation of the magnitude of a VMT rebound effect in California, as are the conclusions drawn by CARB staff from the results of the analysis.

The fact that the Bay Area Metropolitan Transportation Commission (MTC) travel demand model forecasted a similar response is hardly surprising. Metropolitan Planning Organizations (MPOs) in general are focused on identifying congestion deficiencies in their networks, not evaluating the long-term response of travel demand to changes in fuel price and vehicle operating expenses. As a result, they employ similar four-step models (i.e., trip generation, trip distribution, mode choice, and assignment) that are also unable to estimate the magnitude of the VMT rebound effect.

Attachment C-4 presents our independent analysis showing that the rebound effect in California is approximately 16% (i.e., -0.16), which is consistent with the literature for the nationwide rebound effect. A separate analysis by NERA reaches the conclusion that the rebound effect is 17%. By ignoring the rebound effect, CARB has overstated the fuel savings by approximately 17%.

[1] Telephone conversation between Bob Dulla and Hong Kim, September 13, 2004.

Net Effect of the Errors in the ISOR Materials

The errors outlined above do not include several major simplifying assumptions in the CARB staff analysis, which, as indicated at the beginning of this report, are unsupported in the ISOR materials. Those include (1) the assumption that there are sufficient economic and engineering resources to make the required design changes by 2016; (2) the assumption that design changes necessary for compliance will be deployed nationwide; and (3) the assumption that MDPVs will have no significant effect on the cost of compliance with the standards proposed for light-duty trucks. Accepting those assumptions for purposes of this analysis, which CARB's process of delaying information and analyses has required, we conclude that an average per-vehicle cost of compliance should be estimated at $4,573 for vehicles that the proposed rules would classify in the PC/LDT1 category, compared to the $1,064 estimate in the ISOR materials. The average compliance costs in the LDT2/MDPV category defined by CARB, accepting the same three assumptions, would be $1,308, compared to the ISOR materials' estimate of $1,029.

Ignoring the rebound effect, gasoline savings estimated on the same basis would be 1,605 gallons for PC/LDT1s (compared with 2,283 estimated based on the ISOR materials) and 774 gallons for LDT2/MDPVs (compared with 2,644 based on the ISOR materials). Accounting for a 17% rebound effect, the gasoline savings decrease to 1,403 gallons for PC/LDT1s and 655 gallons for LDT/MDPVs.

Ignoring the rebound effect, Sierra's NPV estimates for the fuel savings that result from the proposed regulations are $1,810 for PCs/LDT1s and $872 for LDT2/MDPVs. With the rebound effect, the NPV of the fuel savings decreases to $1,582 for PCs/LDT1s and $738 for LDT2/MDPVs. Using CARB's assumptions, the NPV of the fuel savings would be $2,773 for PC/LDT1 and $3,090 for LDT2.

The net effect of the specific errors identified in the above analysis is that the actual cost of the proposed standards will exceed an optimistic estimate of the present value of the fuel savings for an average California driver by a factor of approximately 200%. Few, if any, customers would be more willing to pay the increased cost of the proposed standards, if their alternative was the current program in which the national government sets standards relating to fuel consumption. The results of the proposed regulation can therefore be expected to include reduction in new vehicle sales, longer retention of older vehicles on the road, and an increase in ozone precursor emissions. The magnitude of this effect is quantified in a joint report by NERA and Sierra being provided under separate cover.